Faculty Working Papers

INVESTMENT HORIZON, RISK PROXIES AND MUTUAL FUND PERFORMANCE: AN EMPIRICAL INVESTIGATION

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Summary:

Monthly, quarterly and annual rates of return for 100 mutual funds are used to empirically investigate the impact of investment horizon on the measurement of mutual fund performance. It is found that the investment horizon exit some impacts on the measurement of mutual fund performance in both relative and absolute sense.

Investment Horizon, Risk Proxies
And Mutual Fund Performance: An Empirical Investigation

I. Introduction

Treynor [23], Sharpe [19] and Jensen [7] have devised single-parameter portfolio performance measures. These three measures simultaneously use a portfolio's risk and return statistics to derive a performance index number which can be used to rank the performance for a group of heterogeneous portfolios. Friend and Blume [3] reported the possibility of biases in the Treynor, Sharpe and Jensen portfolio performance measures in an empirical study using monthly returns. Klemkosky [8] used quarterly mutual fund data and reported finding similar biases in these measures. Neither of these initial studies, however, delved very deeply into discerning the causes for the biases they observed.

Levy [13] showed that Sharpe's measure will be biased unless the investment horizon used in empirical work corresponds to the investor's true investment horizon. Similarly, Levharri and Levy [12] have shown that Treynor's measure gives biased empirical performance rankings unless the true investment horizon is employed. Lee [9] has shown that the risk-return relationship measured empirically will be non-linear unless the true investment horizon is used. Since the Treynor, Sharpe and Jensen models are all based on linear relationships, Lee's evidence on non-linear results further pinpoints the nature of possible biases in these models.

Stone [21] has derived a general three-parameter model and shown that the standard deviation, variance, semi-variance, mean absolute deviation, and the probability of an outcome worse than some prespecified level are all special cases of this more general risk measure. Then, Stone went on to show [22] that the risk-return relationship is expected to be linear when the standard deviation is used as a risk proxy. But, Stone's analysis suggested a non-linear relationship when the variance, semi-variance, or mean absolute deviation were used to measure risk. However, Stone's theoretical work ignored the empirical question of the appropriate differencing interval over which to measure the assets' returns.

Hawawini [4], Schwartz and Whitcomb [17], and Smith [20] have shown evidence that financial risk statistics vary with the length of the differencing interval used to measure returns. As a result, a given risk-return relationship may be linear using monthly returns but non-linear using quarterly returns, for example.

The purpose of this paper is to investigate empirically the impact of using different investment horizons (that is, differencing intervals) on the performance measures, and the results obtainable with five different competing portfolio performance measures. A generalized transformation technique derived by Box and Cox [1] is applied to the basic finance theory in an effort to identify the appropriate investment horizon, the most realistic risk proxy, and the most robust portfolio performance measure to use in ranking mutual fund's desirability. Both Spearman's rank correlation and

the product-moment correlation are used to investigate the impact of investment horizon on risk proxy estimates and performance measure estimates.

In the second section of this paper the well-known Treynor, Sharpe, and Jensen and two other portfolio performance measures are defined. Section three presents empirical evidence from a sample of 100 mutual funds. Bias is shown to exist in all five of the performance measures. In the fourth section the Box-Cox generalized transformation technique is used to measure non-linearities in the risk-return relationships. Monthly, quarterly, and annual data from 100 mutual funds over the period from January 1965 to December Of 1972 inclusive are used for empirical tests. The impact of using the monthly, quarterly and annual differencing intervals on the linearity of the various risk-return tradeoffs is also examined. The fifth section of the paper investigates the impact of investment horizon on the ranking of alternative performance measure estimates. Both rank correlation and product-moment correlations are used to investigate the impact of ranking mutual fund performance. The results of this study are summarized in Section six.

II. Definitions of Five Performance Measures

The Treynor, Sharpe and Jensen portfolio performance measures for the ith mutual fund are calculated as shown in equations (1), (2) and (3) respectively.

(1) $T_i = \overline{(r_i - R)} / b_i$

where r_{it} denotes the non-compounded single-period rate of return in period t for the $i\underline{th}$ portfolio; R_t represents the riskless rate of interest observed in the $t\underline{th}$ time period; and their averaged difference, $\overline{(r_i - R)}$, measures the arithmetic average risk premium; b_i is the beta systematic risk coefficient for fund i; and, T_i denotes Treynor's performance index for the $i\underline{th}$ portfolio.

(2) $S_i = \overline{(r_i - R)} / \sigma_i$

where S_i is Sharpe's performance measure for fund i and σ_i is the fund's standard deviation of returns.

(3) $(r_{it} - R_t) = J_i + B_i(r_{mt} - R_t) + u_{it}$ for $E(u_{it}) = 0$.

Equation (3) is a time-series OLS regression for the $i\underline{th}$ fund. The $t\underline{th}$ time period's risk premium for fund i, $(r_{it} - R_t)$, is regressed onto the simultaneous risk premium for the market portfolio, $(r_{mt} - R_t)$. The systematic risk is measured by the slope coefficient, B_i. Jensen's performance measure is the OLS intercept coefficient, J_i, a measure of unusual returns.

Equation (4) defines a performance measure which is similar to Sharpe's measure, however, it uses the semi-deviation, denoted s_i, as a risk proxy instead of the standard deviation.

$$(4) \quad Ss_i = \overline{(r_{it} - R_t)} / s_i$$

The semi-deviation is a risk surrogate proposed by Markowitz [15, Chapter 9] to measure "downside risk."

Equation (5) defines another reformulation of Sharpe's performance measure which uses the ith fund's mean absolute deviation, denoted MAD_i, as a risk surrogate.

$$(5) \quad Sm_i = \overline{(r_{it} - R_t)} / MAD_i$$

The MAD_i is a more efficient risk statistic than σ_i because the MAD_i is less sensitive to outlying returns (because it does not square them). Klemkosky tested the T, S, J, Ss and Sm performance measures and reported biases using quarterly returns from 40 mutual fund's [8]. Further delineation of these possible biases is explained in the next section.

III. Evaluating Bias In The Performance Measures

The first published study [3] documenting bias in the Treynor, Sharpe and Jensen portfolio performance measures was prepared by Friend and Blume (FB hereafter). FB used both continuously compounded and non-compounded monthly returns from hypothetical portfolios they created from samples of representative NYSE stocks. FB estimated cross-sectional regressions like the ones shown in equations (6a) through (6c) to evaluate possible relationships between the

performance measures and their associated risk statistics.

(6a) $$T_i = c_0^a + c_1^a b_i + z_i^a$$

(6b) $$S_i = c_0^b + c_1^b \sigma_i + z_i^b$$

(6c) $$J_i = c_0^c + c_1^c B_i + z_i^c$$

where c_0 is the regression intercept, c_1 is a slope coefficient, and z_i is the unexplained residual for the ith portfolio, $E(z) = 0$.

Cross-sectional equations (6d) and (6e) were also estimated by Klemkosky[8] in order to evaluate possible bias in the Ss and Sm portfolio performance measures defined above in equations (4) and (5), respectively.

(6d) $$Ss_i = c_0^d + c_1^d s_i + z_i^d$$

(6e) $$Sm_i = c_0^e + c_1^e (MAD_i) + z_i^e$$

Klemkosky used non-compounded quarterly returns from a sample of 40 mutual funds to estimate equations (6a) through (6e) and extend the FB study using mutual fund data.

The FB and Klemkosky studies both reported positive and significant bias in all the portfolio performance measures they examined, except in the Ss_i measure defined in equation (4). These biases were documented by regression slope coefficients, c_1, which were significantly greater than zero.

Both the FB and the Klemkosky studies mentioned that the borrowing rate, B, exceeding the lending rate, L, as being the most likely cause of the biases they documented. The resulting nonlinear relationships are illustrated in Figures 1 and 2. The solid lines represent the opportunities for investing when $B > L$.

------------------Insert Figures 1 and 2 here------------------------

The possible nonlinear relationships as indicated in both Figures 1 and 2 will be tested, by using data associated with different investment horizons. Table 1 shows the estimates of equations (6a) through (6e) using 96 monthly, 32 quarterly, and seven annual non-compounded rates of return from 100 mutual funds. The sample data covers January 1965 through December 1972.[1] The statistics from equations (6a) through (6e) indicated the presence of a statistically significant positive linear relationship between the five performance measures and their associated risk statistics.

-------------------Insert Table 1 here------------------------------

Table 1 indicates that the coefficients of determination (R^2) for 15 alternative measures are generally smaller than those found by FB and Klemkosky. It is also interesting to note that the $\bar{R}^2$ is not independent of the investment horizon. In the following section Box and Cox's generalized transformation technique [1] will be used to test the linearity of the risk-return relationship.

FIGURE 1--Non-Linear Opportunity Locus In $[\sigma, E(r)]$ Space

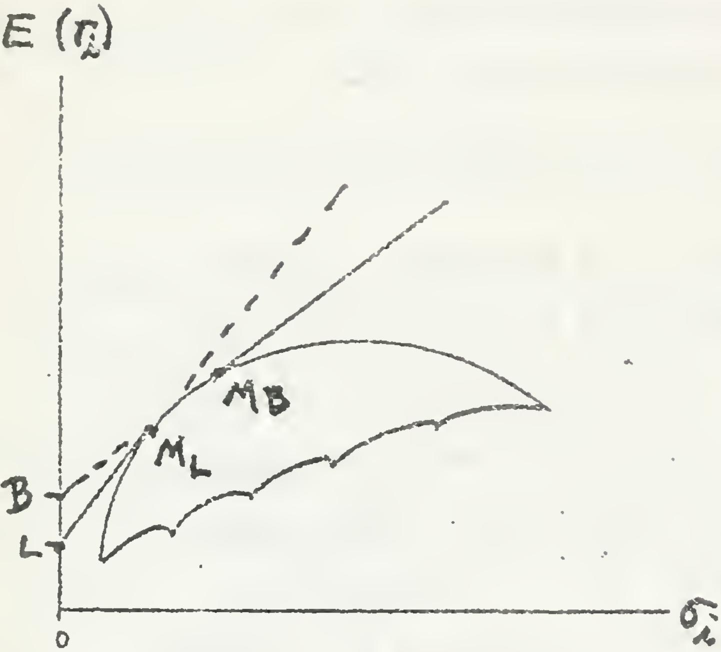
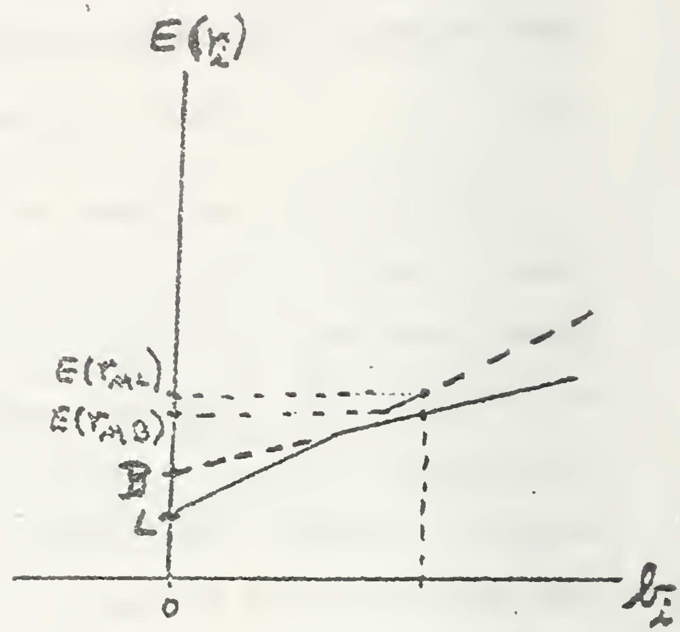


FIGURE 2 -- Non-Linear Opportunity Locus In $[b, E(r)]$ Space



both the linear and log-linear forms as special cases and provides a generalized functional form to test which form is the most appropriate to explain the observed risk-return relationship. For the case when λ equals zero and equation (7) is presumed to be continuous. A stochastic error term (e) may be added to equation (7) to obtain equation (8) for testing the functional relationship between the risk-return tradeoff.

$$(8) \quad \bar{R}_i(\lambda) = A + B\, Y_i(\lambda) + e_i$$

where

$$(8a) \quad \bar{R}_i(\lambda) = (\bar{R}_i^{\lambda} - 1)/\lambda$$

$$(8b) \quad Y_i(\lambda) = (Y_i^{\lambda} - 1)/\lambda$$

$$(8c) \quad A = \left[(a + b) - 1\right]/\lambda$$

$$(8d) \quad e_i \sim N(0, \sigma_e^2)$$

Box and Cox [1] have derived the maximum logarithmic likelihood shown in equation (9) by using the maximum likelihood method to determine the functional form parameter, .

$$(9) \quad Lmax(\hat{\lambda}) = -n \log\left[\hat{\sigma}_e(\lambda)\right] + (\lambda - 1)\sum_{i=1}^{n} \log(\bar{R}_i) + c$$

where c represents a constant term, n is the number of mutual funds (that is, 100), and $\sigma_e(\lambda)$ is the functional notation for the estimated regression residual standard error from equation (8) after the dependent and independent variables are transformed as shown in equations

IV. The Linearity Of The Risk-Return Relations

Stone [22] has shown theoretical evidence that the risk-return relationship should be linear for the standard deviation, but, non-linear for the variance, semi-variance, mean absolute deviation risk proxies. To test Stone's findings, and also, to test the linearity assumptions on which the T, S, J, Ss and Sm portfolio performance measures are based, the Box-Cox transformation technique is used to derive a generalized risk-return relationship suitable for estimation.

Following Box-Cox [1] and Zarembka [24] the generalized risk-return relationship shown in equation (7) is defined.

$$(7) \quad \bar{R}_i^{\lambda} = a + b \; Y_i^{\lambda}$$

Where $\bar{R}_i = (1 + \bar{r}_i)$ = unity plus the ith portfolio's arithmetic average rate of return. The greek letter lambda, λ, is a functional form parameter which will be estimated. Y_i represents some risk surrogate which is being used to explain the ith matual fund's arithmetic average return for a cross-sectional sample of i=1, 2, ...100 funds, it represents either the standard deviation of returns, the variance, the semi-variance, the mean absolute deviation, or the beta coefficient. Equation (7) reduces to a linear form when lambda equals positive unity. Or, if λ equals zero equation, (7) becomes log-linear. That is, the equation (7) includes

nd (8b), respectively. After equation (8) is estimated over a range of values for λ, equation (9) is used to determine the optimum value for λ. The optimal value of λ is that value of which miximizes the logarithmic likelihood, equation (10), over the parameter space.

The likelihood ratio method derived in [1] indicates the 95% confidence limits for λ shown in equation (10).

$$(10) \quad \text{Lmax}(\hat{\lambda}) - \text{Lmax}(\lambda) < .5\chi_1^2(.05) = 1.92$$

The 95% confidence region for λ is used to determine the true functional form. If the maximum likelihood value of λ is significantly different from zero, for example, this implies that both the linear form and the log-linear form is not descriptive of the empirically observed risk-return relationship.

The dependent variable, $\bar{R}_i$, and whichever risk surrogate was being used to estimate the true functional form were transformed in accordance with equations (8a) and (8b) for values of λ ranging from -1.2 up to 1.6 at intervals of two-tenths. Thus, fifteen regressions were estimated for each differencing interval and risk proxy combination. The maximum likelihood value of λ for every risk-return relation at the monthly, quarterly and annual differencing intervals was calculated with equation (9) and is listed in Tables Tables 2A through 2E.

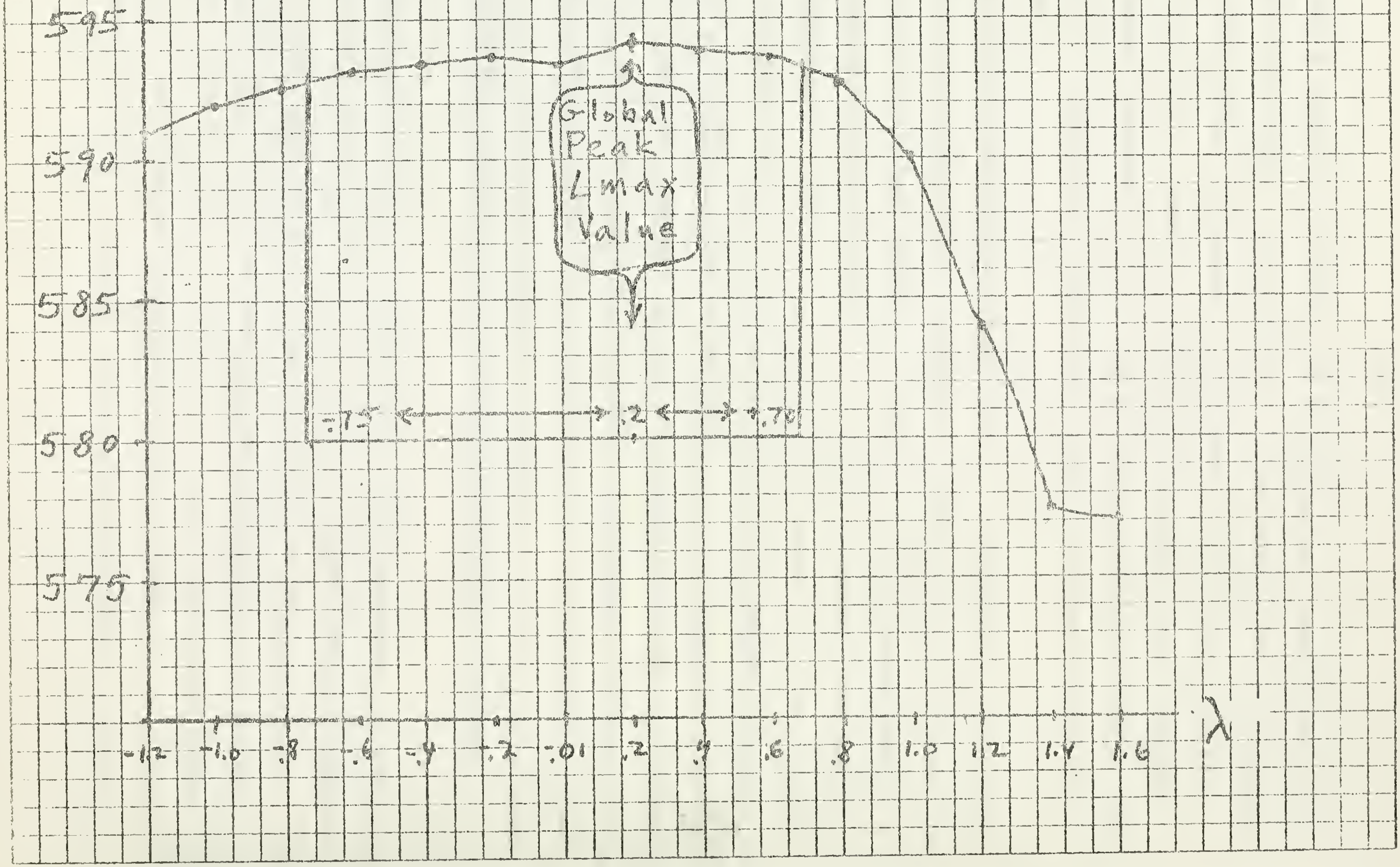
For illustration purposes, the Lmax(λ) values for the average return and mean-absolute-deviation relation with monthly returns

is plotted in Figure 3. The vertical bars at -.70 and +.75 values for in Figure 3 indicate the 95% confidence region for the maximum likelihood estimates of λ, denoted $\hat{\lambda}$. Note that the maximum likelihood value for lambda of λ = .2 is significantly different from linear (that is, when λ = 1.0). But,,it is not significantly different from the log-linear form (when λ = 0). The maximum likelihood values which maximized equation (9) were similarly calculated for all five risk-return relationships being examined here at each of the three different investment horizons being tested: these results are summarized in Table 3.

-------------------Insert Table 3 and Figure 3 here-----------------

The results in Table 3 show that if the mean absolute deviation (MAD hereafter) measured either quarterly or annually is used as a risk proxy, then the functional form parameter, λ, is not significantly different from zero or unity. In contrast, if the beta coefficient calculated with monthly, quarterly, or annual returns is used to explain average returns, the λ is significantly different from zero. Likewise, if the monthly, quarterly and annual semi-variance risk surrogates are used, the λ is significantly different from one but not different from zero. And if the variance is used the results are identical to the semivariance results. Finally, if the standard deviation is used to explain average returns, the risk-return relationship is identical to that obtained using the MAD; that is, both the linear and log-linear values of λ are within the acceptance region using quarterly and

Figure 3 -- Lmax As Function Of λ For MA1 - Average Monthly Return Estimates Of Equation (8)



and annual returns. If linear risk-return relationship is used as a criteria for selecting performance measure, then the performance measures using the beta coefficient as a risk proxy (namely, the Treynor and the Jensen measures) are most desirable. If Sharpe's type of total risk measure is used to gauge the performance of mutual funds, then MAD and σ, in terms of either quarterly data or annual data, should be used as a risk proxy to reduce the bias.

V. Investment Horizon And The Ranking of Performance Measure

To investigate the impact of investment horizon on the ranking of performance measures, both Spearman's rank correlation coefficient and the product-moment correlation coefficient are shown in Table 4. From the average of both the Spearman and the product-moment correlations it can be concluded that the change of investment horizons does not substantially affect the ranking of mutual fund performance. However, Jensen [7] has argued that the performance measures can also be used to evaluate investment performance in an absolute sense. Therefore, the generalized transformation technique discussed above in section IV should be used to determine the appropriate performance measure and its appropriate investment horizon.

Elton, Gruber and Pudberg (EGP hereafter) have used Sharpe's performance measure to derive the simple criteria for optimal portfolio selection. Gressis, Philippatos and Hayya (GPH hereafter) have investigated the impact of different horizons on efficient portfolio selection. The results of this section can be integrated with EGP's results to simplfy the procedure for testing the issue

raised by GPH.

VI. Summary

In this paper, both the risk-return relationship and correlation analysis are used to empirically determine the appropriate investment performance measure to be used to evaluate mutual fund performance. It appears that the investment horizon is not an important factor in using the five alternative performance measures for ranking mutual fund performance. However, if the generalized transformation technique is used to test the linearity of risk-return relationship, is is found that both the investment horizon and risk proxy are important factors in choosing the appropriate investment performance measures. Our data indicate that both the Treynor and Jensen measures are theoretically more desireable than the other three performance measures examined here.

FOOTNOTES

[1] The quarterly returns, qr_t, were calculated by multiplying three monthly link relatives, $(1 + r_t)$, as follows:

$$qr_t = \left[(1 + r_{t-2})(1 + r_{t-1})(1 + r_t)\right] - 1.0$$

The annual returns were likewise prepared by multiplying twelve monthly link relatives. This procedure minimizes the measurement error and bias analyzed in some detail by Mains [14].

Table 1
Estimates of Equations (6a) Through (6e) To Measure Bias

Performance Measure	Differencing Interval	$c_0(t_0)$	$c_1(t_1)$	$\bar{R}^2$
S_i	Monthly	-.0573(-2.5905)	2.1015(4.3017)	.1503
S_i	Quarterly	-.1223(-3.6463)	2.1801(5.4475)	.2246
S_i	Annual	-.2088(-2.4951)	2.4622(3.6416)	.1102
T_i	Monthly	-.0085(-5.2753	0.0149(6.5828)	.2995
T_i	Quarterly	-.0377(-5.2338	0.0602(6.0088)	.2618
T_i	Annual	-.1365(-2.6438)	0.2091(2.7167)	.0605
J_i	Monthly	-.0030(-3.6929)	0.0041(3.5321)	.1039
J_i	Quarterly	-.0101(-4.5054)	0.0133(4.2798)	.1488
J_i	Annual	-.0293(-3.9143)	0.0356(3.2585)	.0885
Ss_i	Monthly	-.0949(-3.4275)	4.1076(5.1706)	.2063
Ss_i	Quarterly	-.1557(-3.6616)	3.5751(5.4845)	.2270
Ss_i	Annual	-.2133(-2.0911)	3.3140(3.2854)	.0905
Sm_i	Monthly	.0011(.0661)	41.5328(3.0508)	.0774
Sm_i	Quarterly	-.0323(-1.1258)	26.9219(4.1597)	.1413
Sm_i	Annual	-.0324(-.4259)	17.8799(2.5249)	.0515

T_i = Treynors measure for the ith fund, S_i = Sharpe's measure, J_i = Jensen's measure, Ss_i = equation (4) measure, Sm_i = equation (5) measure, c_0 = intercept term, c_1 = slope coefficient of linear risk variable, $\bar{R}^2$ = adjusted coefficient of determination.

Table 2A

Lmax For 100 Mutual Funds Equation (8) With Beta As The Risk Measure

λ \ horizon	Monthly	Quarterly	Annually
-1.2	586.39	472.54	317.19
-1.0	587.36	473.52	317.74
- .8	588.54	474.92	318.74
- .6	589.92	476.80	320.34
- .4	591.44	479.16	322.54
- .2	592.99	481.86	325.06
- .01	594.39	484.43	327.32
.2	595.69	486.93	329.28
.4	596.60	488.71	330.51
.6	597.16	489.81	331.15
.8	597.38	490.31	331.32
1.0	597.30	490.32	331.10
1.2	596.99	489.91	330.57
1.4	596.50	489.37	329.82
1.6	595.88	488.60	328.89

Table 2B

Lmax For 100 Mutual Funds, Equation ('8) With MAD As The Risk Measure

λ \ Horizon	Monthly	Quarterly	Annually
-1.2	591.45	480.38	324.94
-1.0	592.07	481.31	325.25
- .8	592.61	482.20	325.52
- .6	593.11	483.03	325.74
- .4	593.51	483.75	325.90
- .2	593.79	484.32	326.00
-.01	593.72	484.74	326.03
.2	594.06	485.03	325.97
.4	593.98	485.12	325.84
.6	593.75	485.04	325.84
.8	592.84	484.81	325.36
1.0	590.72	484.44	325.00
1.2	584.55	483.86	324.57
1.4	577.55	482.95	324.07
1.6	577.42	481.08	323.52

Table 20

L max For 100 Mutual Funds, Equation (8) With Semivariance
As The Risk Measure

λ \ horizon	Monthly	Quarterly	Annually
-1.2	586.87	474.00	320.79
-1.0	587.81	475.07	321.77
- .8	588.84	476.49	322.81
- .6	589.84	478.24	323.80
- .4	590.66	480.14	324.60
- .2	591.14	481.84	325.14
-.01	591.09	482.91	325.35
.2	589.14	483.19	325.23
.4	587.58	482.77	324.79
.6	579.25	481.44	324.09
.8	567.37	478.05	323.17
1.0	575.14	471.15	321.98
1.2	579.80	467.31	319.77
1.4	580.57	467.91	314.86
1.6	580.71	468.13	312.84

Table 2D

L max For 100 Mutual Funds, Equation (8) with Variance As The Risk Measure

λ \ Horizon	Monthly	Quarterly	Annually
-1.2	587.42	475.36	321.63
-1.0	588.28	476.65	322.67
- .8	589.19	478.24	323.82
- .6	590.05	480.04	324.97
- .4	590.76	481.86	325.99
- .2	591.18	483.39	326.78
-.01	<u>591.22</u>	484.32	327.26
.2	590.10	<u>484.60</u>	<u>327.46</u>
.4	589.07	484.32	327.36
.6	585.02	483.48	326.97
.8	573.55	482.06	326.34
1.0	574.43	477.79	325.50
1.2	578.61	470.09	324.40
1.4	580.18	467.69	322.94
1.6	580.64	467.91	319.39

Table 2E

Lmax For 100 Mutual Funds, Equation (8) With Standard Deviation As The Risk Measure

λ \ horizon	Monthly	Quarterly	Annually
-1.2	590.08	480.16	325.42
-1.0	590.46	481.06	325.88
- .8	590.78	481.94	326.29
- .6	591.02	482.73	326.64
- .4	591.16	483.42	326.93
- .2	591.12	483.96	327.14
- .01	591.01	484.34	327.27
.2	591.04	484.58	327.33
.4	590.76	484.62	327.31
.6	590.41	484.57	327.22
.8	589.61	484.26	327.05
1.0	588.84	483.89	326.80
1.2	585.05	483.36	326.49
1.4	580.38	482.67	326.10
1.6	575.94	481.76	325.66

TABLE 3

The Maximum Likelihood Estimates of λ And Their 95% Confidence Regions

	Specification	Investment Horizon	$\hat{\lambda}$	95% Confidence Region For λ
(1)	$\bar{R}_i = a_1 + b_1 b_i$	monthly	.8	.25 ~ 1.65
		quarterly	1.0	.55 ~ 1.62
		annually	.8	.35 ~ 1.25
(2)	$\bar{R}_i = a_2 + b_2(MAD)$	monthly	.2	-.75 ~ .70
		quarterly	.4	-.50 ~ 1.30
		annually	-.01	-1.25 ~ 1.45
(3)	$\bar{R}_i = a_3 + b_3 s_i$	monthly	-.2	-.55 ~ .22
		quarterly	.2	-.19 ~ .61
		annually	.2	-.42 ~ .58
(4)	$\bar{R}_i = a_4 + b_4 \sigma_i^2$	monthly	-.01	-.35 ~ .32
		quarterly	.2	-.33 ~ .69
		annually	.2	-.50 ~ .95
(5)	$\bar{R}_i = a_5 + b_5 \sigma_i$	monthly	-.4	-1.25 ~ .65
		quarterly	.4	-.59 ~ 1.45
		annually	.4	-1.25 ~ 1.65

Table 4

Correlation Coefficients With Two Different Horizons For Each Measure

Simple Correlations			Averaged Correlations	Performance Measure
S-Mo.	Qt.	.99 (.99)	.975 (.97)	Sharpe Measure
	An.	.96 (.95)		
S-Qt.	Mo.	.99 (.99)	.980 (.970)	
	An.	.97 (.95)		
S-An.	Mo.	.96 (.95)	.965 (.950)	
	Qt.	.97 (.95)		
T-Mo.	Qt.	.98 (.92)	.965 (.860)	Treynor Measure
	An.	.95 (.80)		
T-Qt.	Mo.	.98 (.92)	.965 (.935)	
	An.	.95 (.95)		
T-An.	Mo.	.95 (.80)	.950 (.875)	
	Qt.	.95 (.95)		
J-Mo.	Qt.	.98 (.99)	.965 (.980)	Jensen Measure
	An.	.95 (.97)		
J-Qt.	Mo.	.98 (.99)	.970 (.985)	
	An.	.96 (.98)		
J-An.	Mo.	.95 (.97)	.955 (.975)	
	Qt.	.96 (.98)		
S_s-Mo.	Qt.	.99 (.99)	.975 (.970)	S_s Measure
	An.	.96 (.95)		
S_s-Qt.	Mo.	.99 (.99)	.975 (.970)	
	An.	.96 (.95)		
S_s-An.	Mo.	.96 (.95)	.960 (.950)	
	Qt.	.96 (.95)		
S_m-Mo.	Qt.	.99 (.99)	.980 (.970)	S_m Measure
	An.	.97 (.95)		
S_m-Qt.	Mo.	.99 (.99)	.985 (.970)	
	An.	.98 (.95)		
S_m-An.	Mo.	.97 (.95)	.975 (.950)	
	Qt.	.98 (.95)		

Remark: Product moment correlations are in the parenthesis.

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